



Moth ears: bat defense and moth courtship

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Webpage: <http://itg.wfu.edu/connerlab>

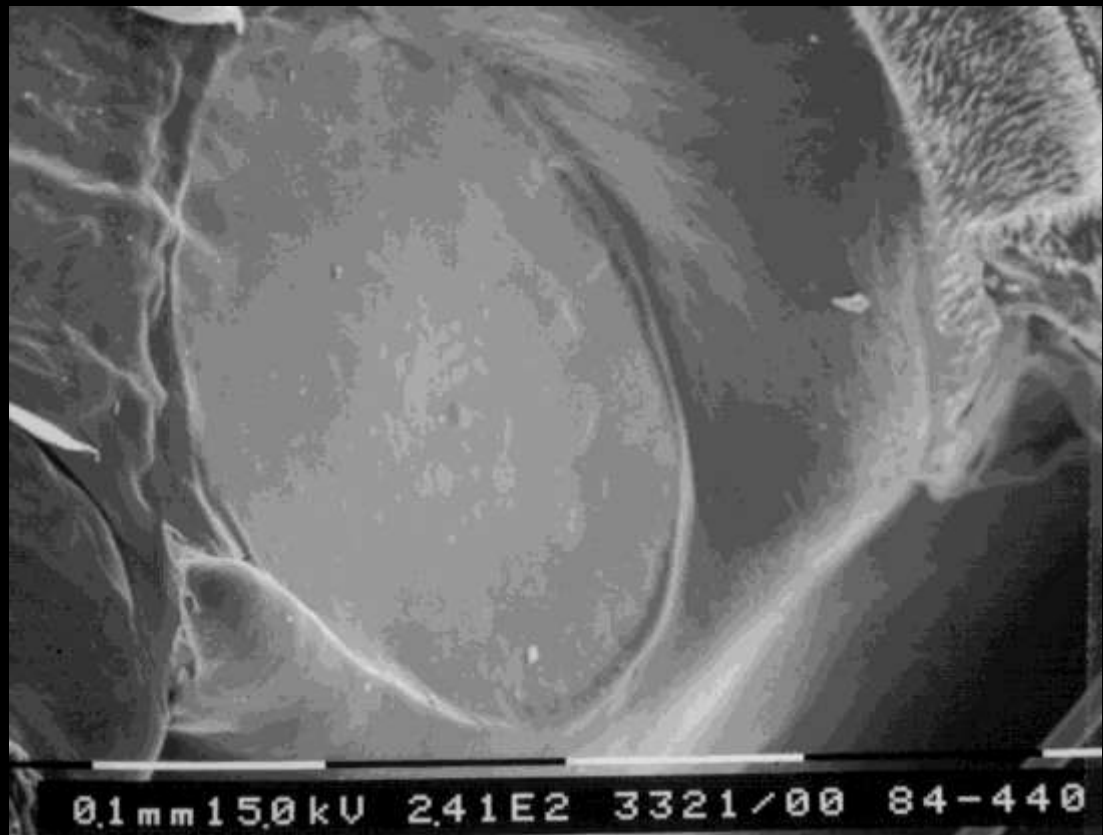
Outline

- Moth ear diversity
- Moths vs. Bats
- Sound in moth courtship



Moth ears: Introduction

- 85% of macrolepidoptera are eared
- “typical” moth ear is called a tympanum
- Thinned cuticle
- Air sac
- 1 - 4 neurons

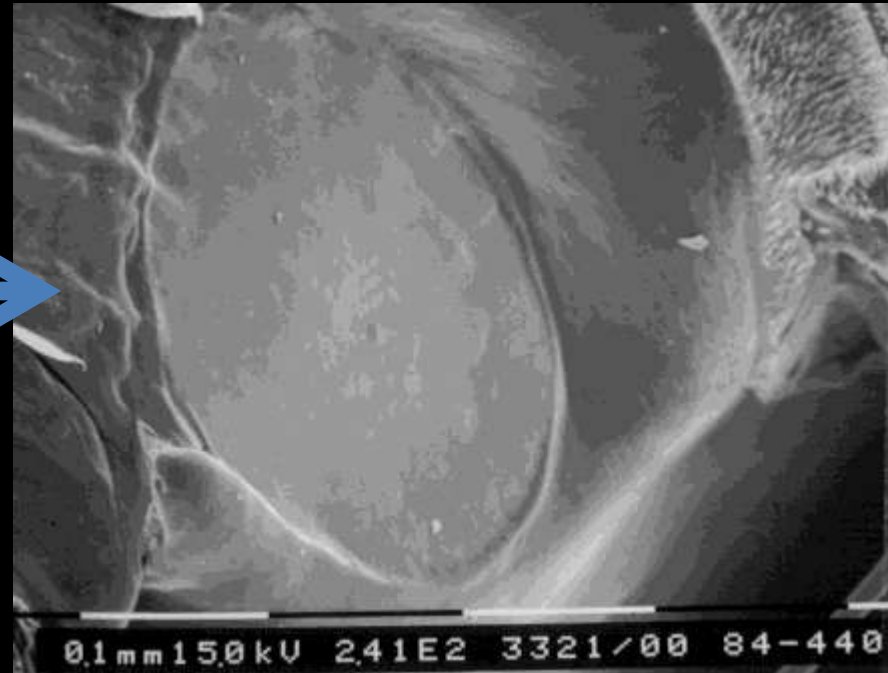
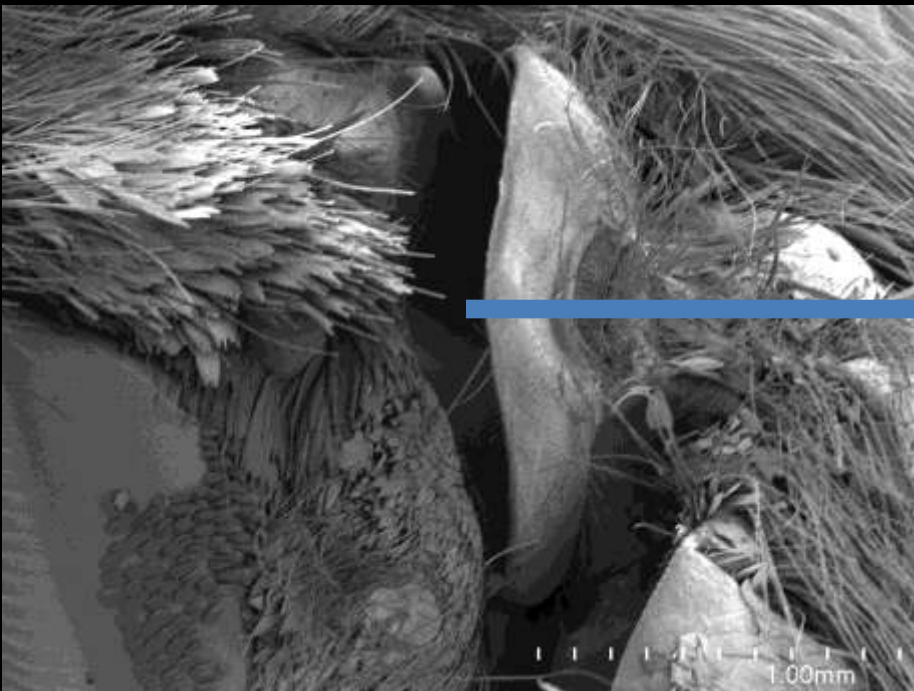


Ear locations - Overview

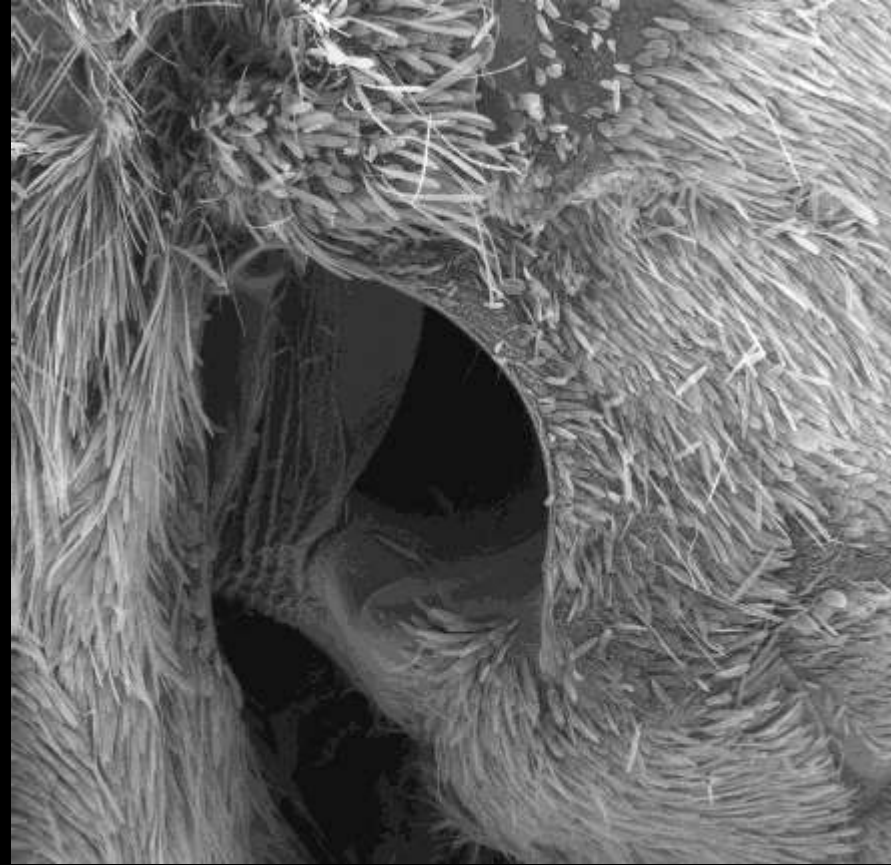
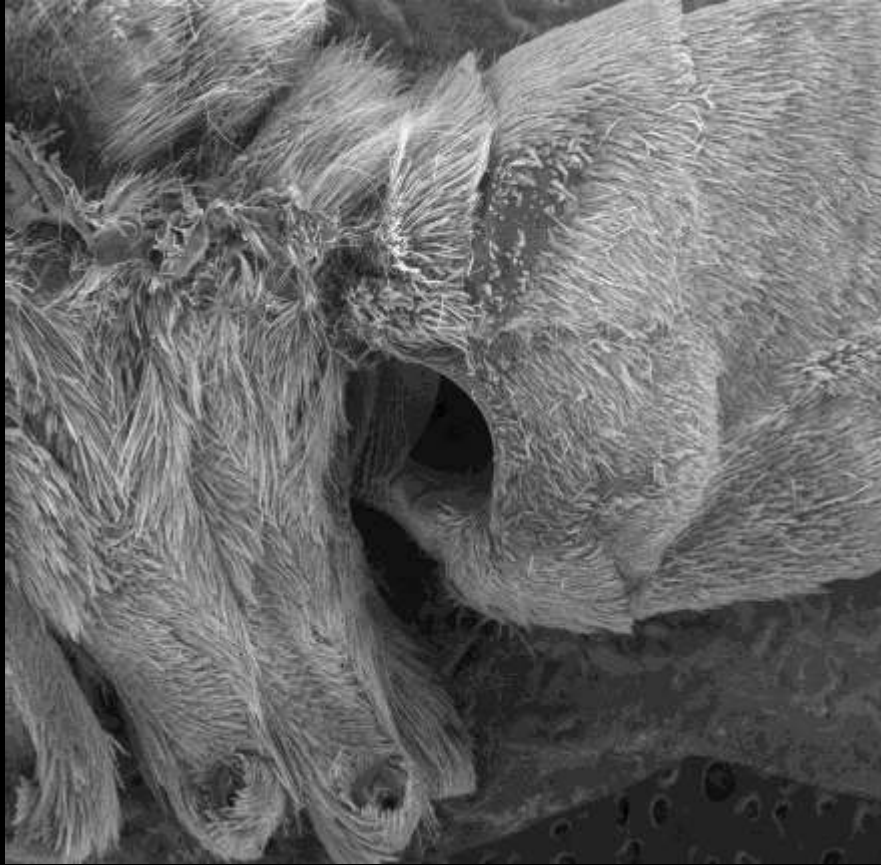
Metathorax	Base of abdomen	Base of forewing	Other
Noctuoidea	Geometridae	Hedylidae	Some Sphingidae
	Pyralidae	Some Thyrididae*	Axiidae
	Crambidae	Some Nymphalidae	Drepanidae
	Uraniidae		
	Some Tineidae*		
	Dudgeoneidae*		

*Needs confirmation

Noctuoid tympanum



Geometrid tympanum



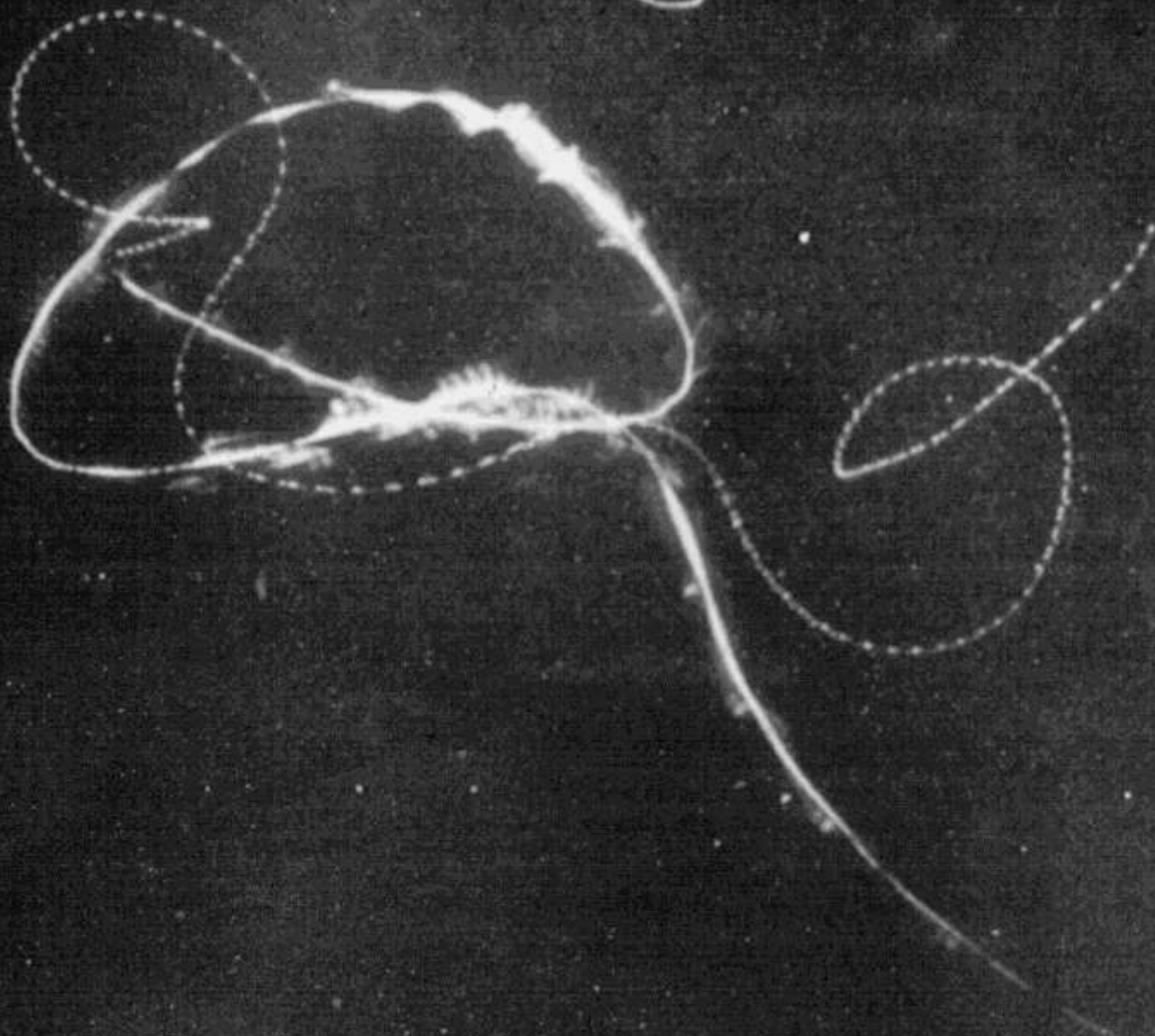
Thyridid Tympanum



Fig. 11.4. Presumed tympanal organ of a Siculodinae (Thyrididae): *Rhodoneura opalinula* ♂. Original SEM photograph (J. Boudinot & J. Minet). Scale line = 0.5 mm. Arrow: "tympanum"; black arrowhead: basal (ventral) swelling of vein Sc (after removal of most of its scales); white arrowhead: linguiform flap.

Sphingid hearing organ





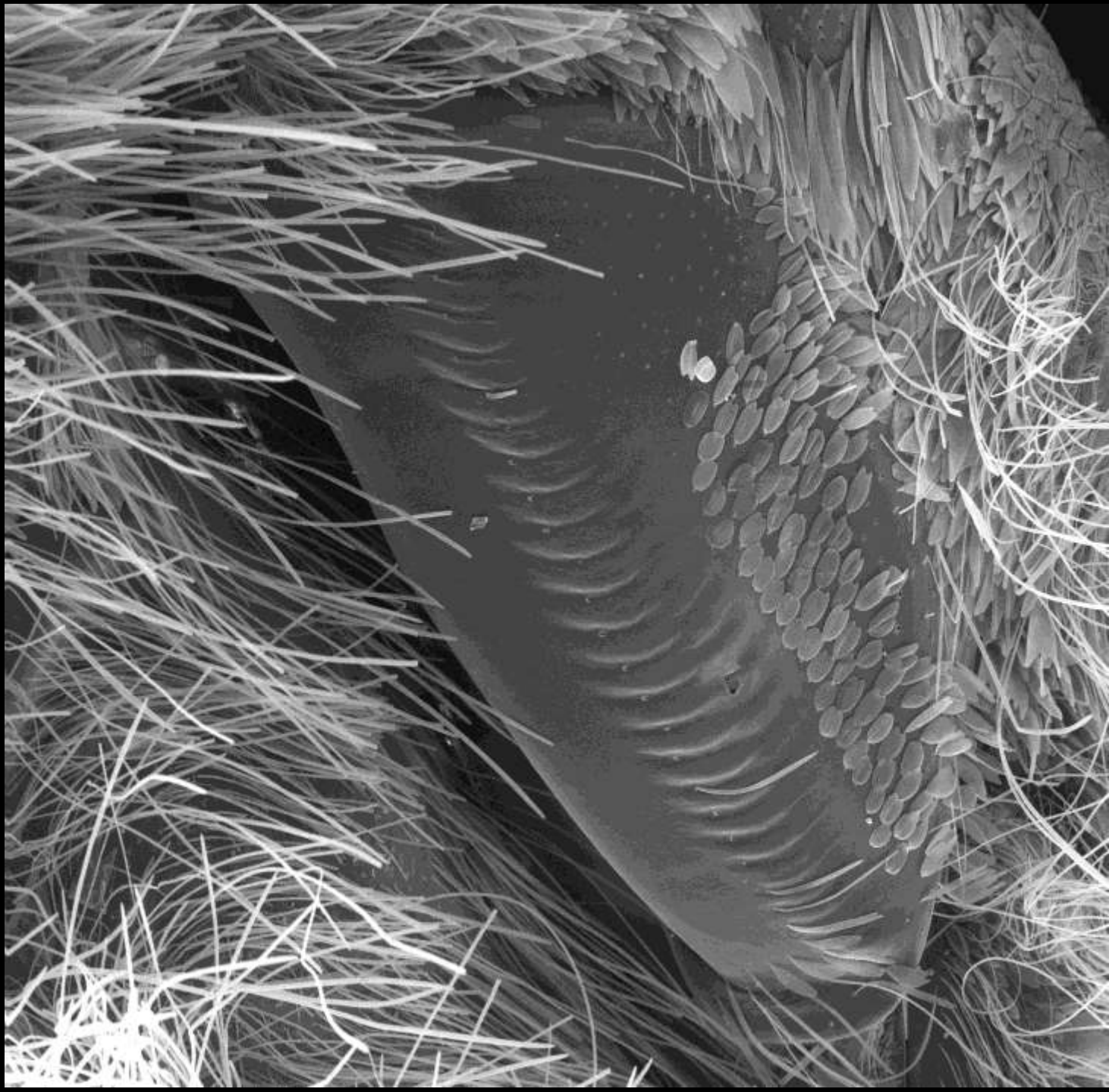
Bats - background

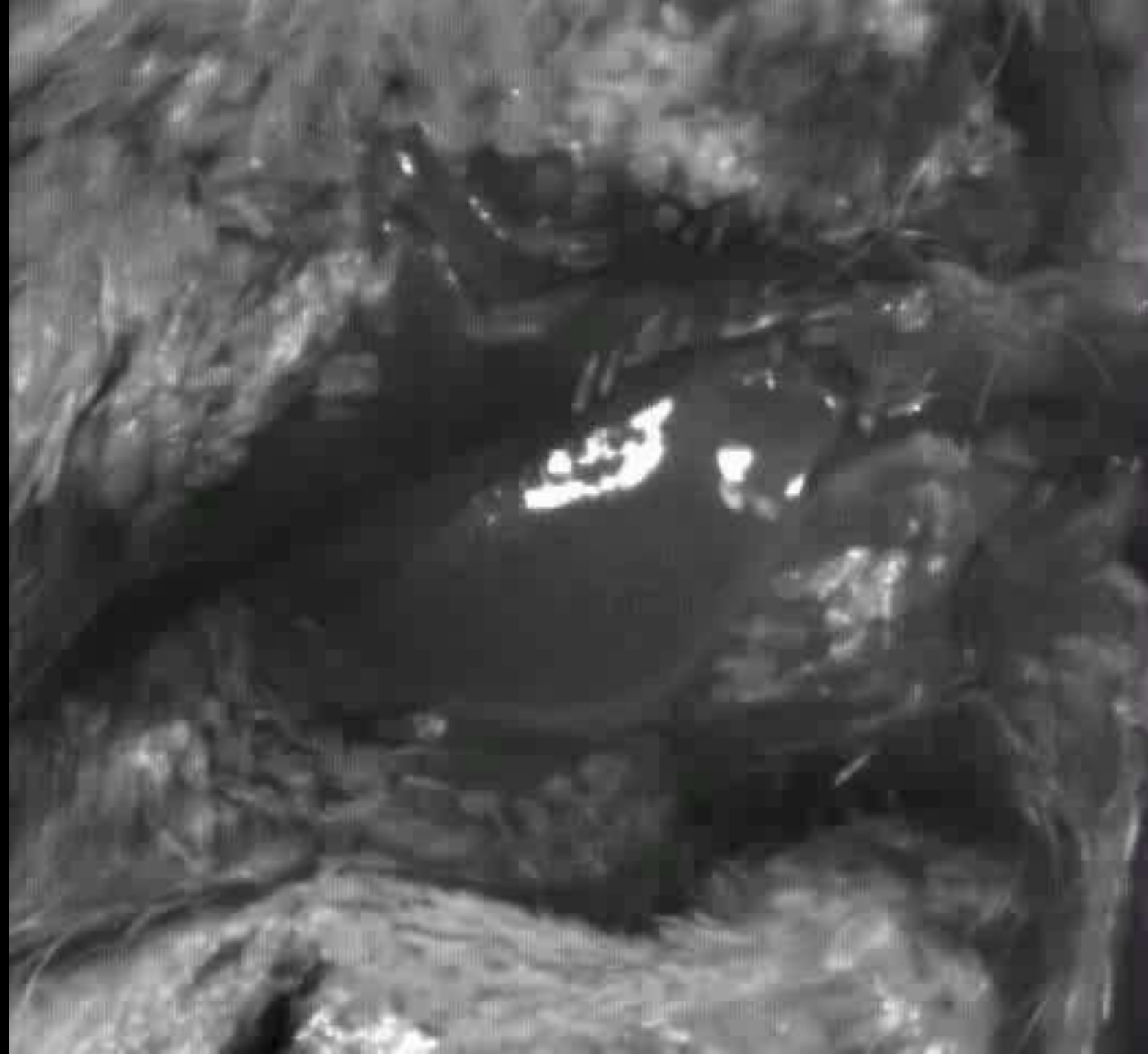
- 1100+ species
 - 70% insectivorous
 - Consummate nocturnal predator





Video: Jesse Barber





Dunning and Roeder 1965



- Moth clicks played via loudspeaker as wild-caught bats tried to catch mealworms
- Bats routinely aborted attacks in response to clicks.
- Bats did not learn to ignore moth clicks

Dunning and Roeder 1965



- “the noisy ultrasonic pulses emitted by the moths could protect them against their predators, the bats”

Nerve Cells and Insect Behavior 1967



- “It appears that the moths’ noise-making ... advertises their distastefulness” Pg. 98

Proposed Click Functions

- Warning
 - Learned avoidance
 - Mimicry



Proposed Click Functions

- Warning
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 - Mimicry
- Jam Sonar
 - Evidence inconclusive



Proposed Click Functions

- Warning
 - Learned avoidance
 - Mimicry
- Jam Sonar
 - Evidence inconclusive
- Startle!
 - Habituation



Methods

- Reared naïve bats
- On each of five-seven nights:
 - Four intact arctiine moths
 - 12 noctuid controls
- Nights eight and nine:
 - Four silent *B. trigona*
 - 12 controls
- Palatability trials



Experimental Paradigm



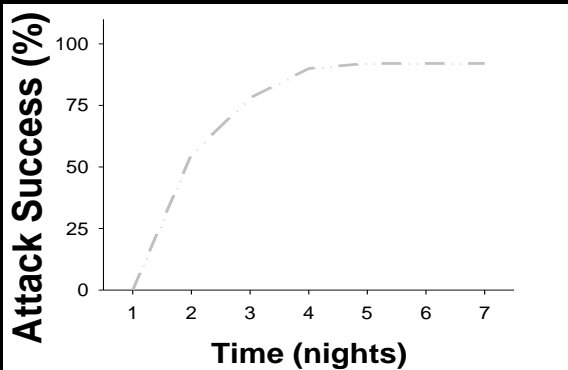
Startle



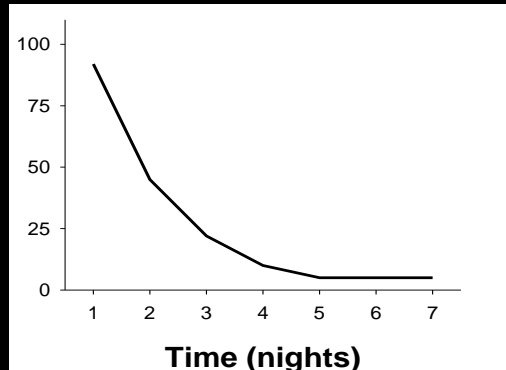
Warning



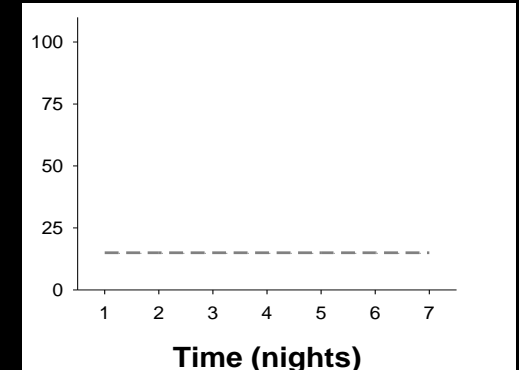
Jamming



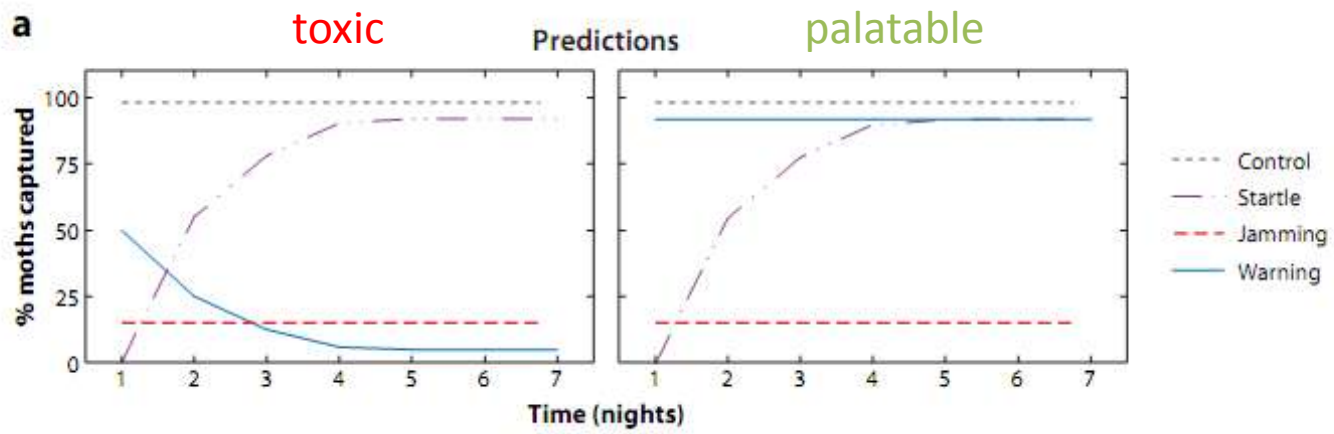
Habituation



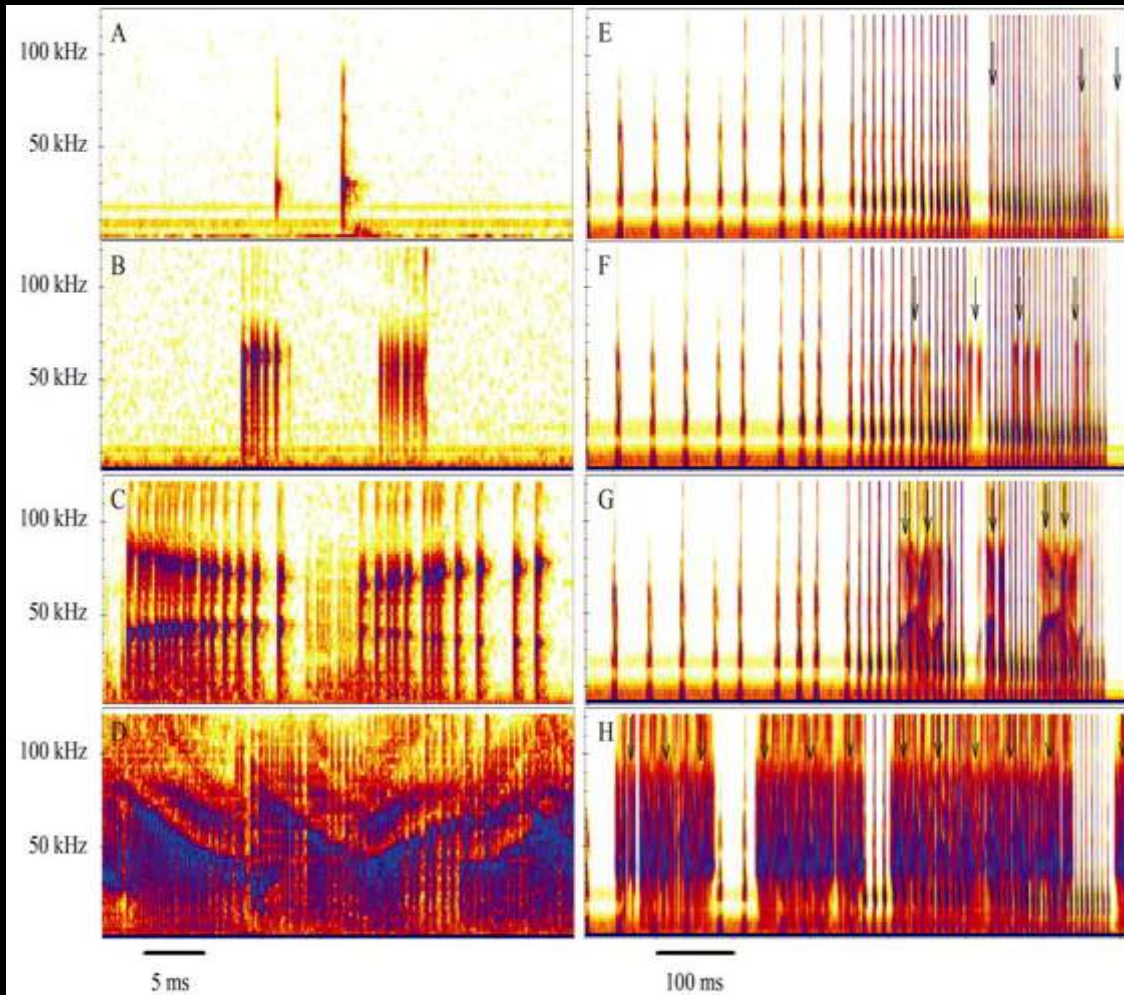
Learned avoidance



Constant



Moth Click Diversity



*Ctenucha
venosa*



*Cisthene
martini*



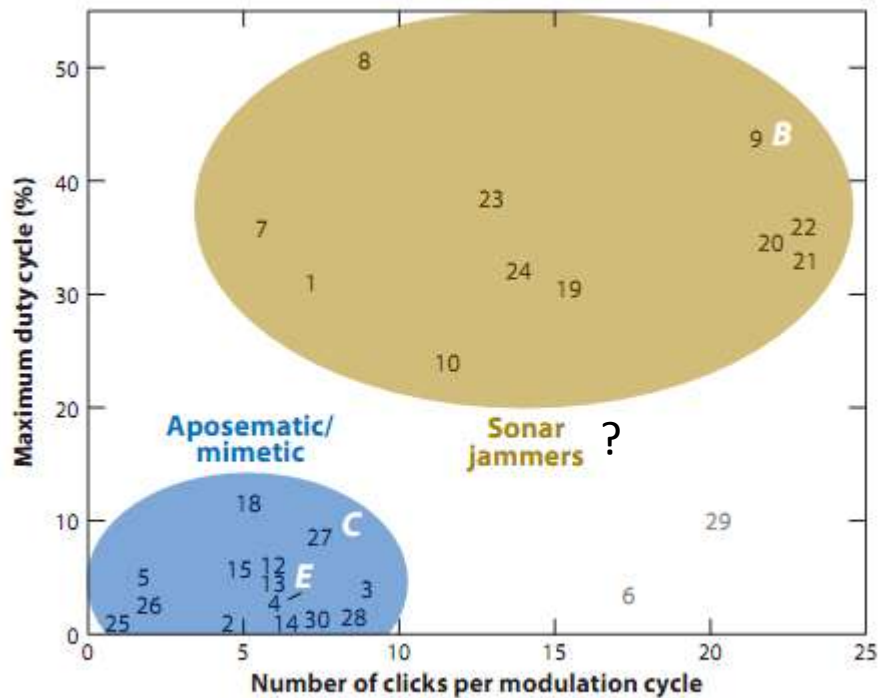
*Carales
arizonensis*



*Bertholdia
trigona*

Images: Moth Photographers Group
Website

Moth Click Diversity

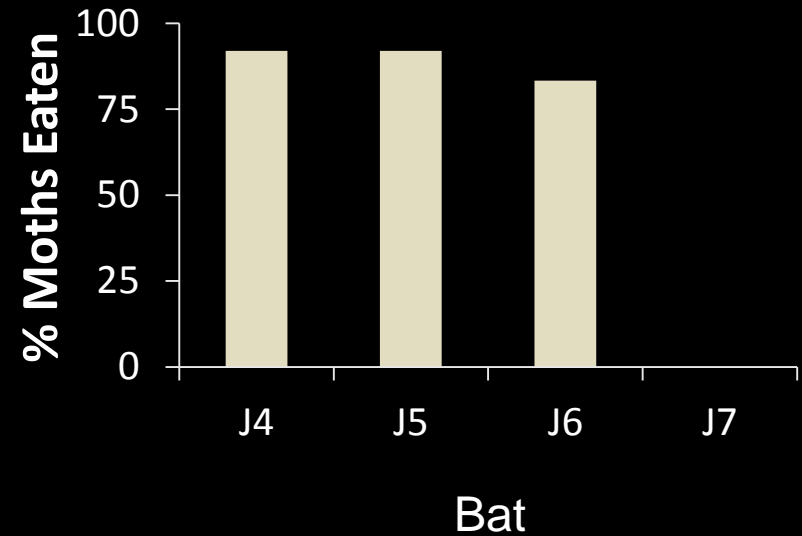


Corcoran et al. 2010 *Current Zoology*

Conner and Corcoran 2012 *Annual Review of Entomology*

Results -- Palatability

Stationary Feeding

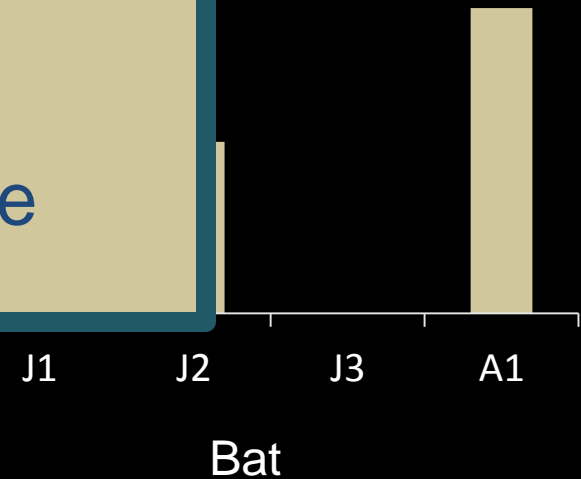


Results -- Palatability

Feeding on the Wing



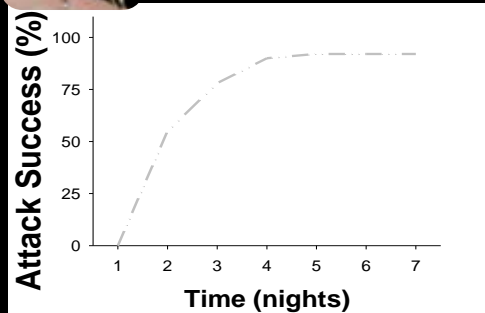
Conclusion:
Moths palatable



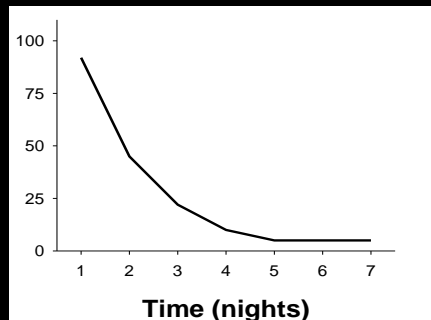
Results – Attack Success



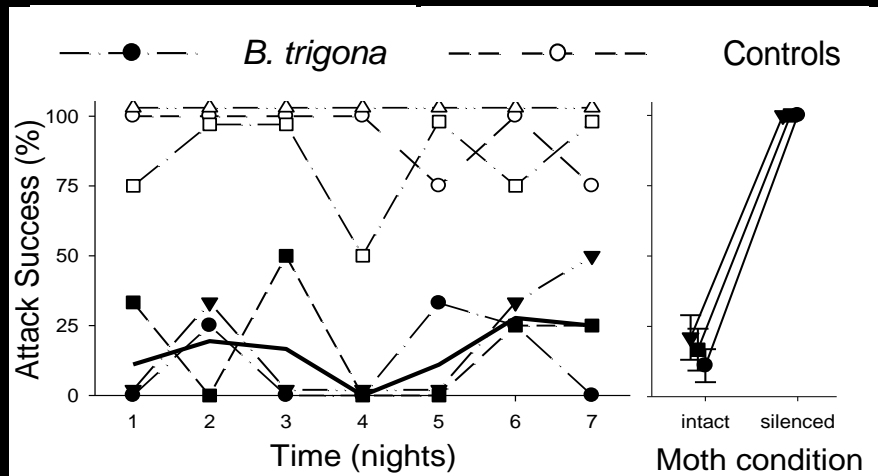
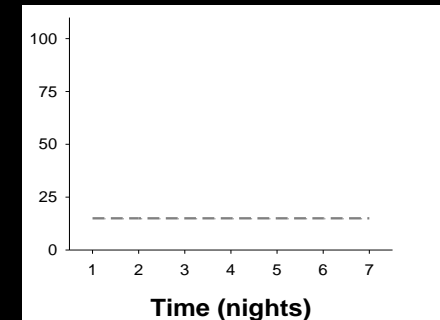
Startle



Warning



Jamming

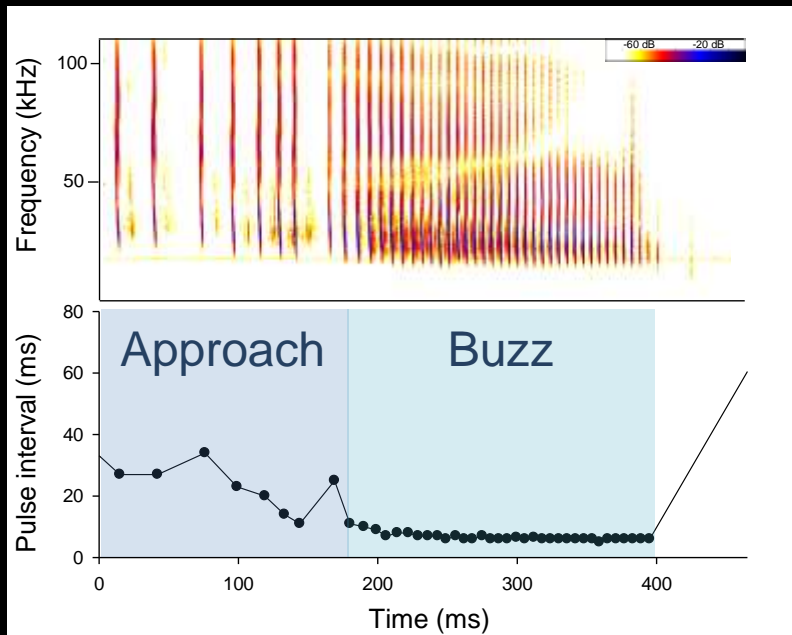


⊙ *B. trigona*

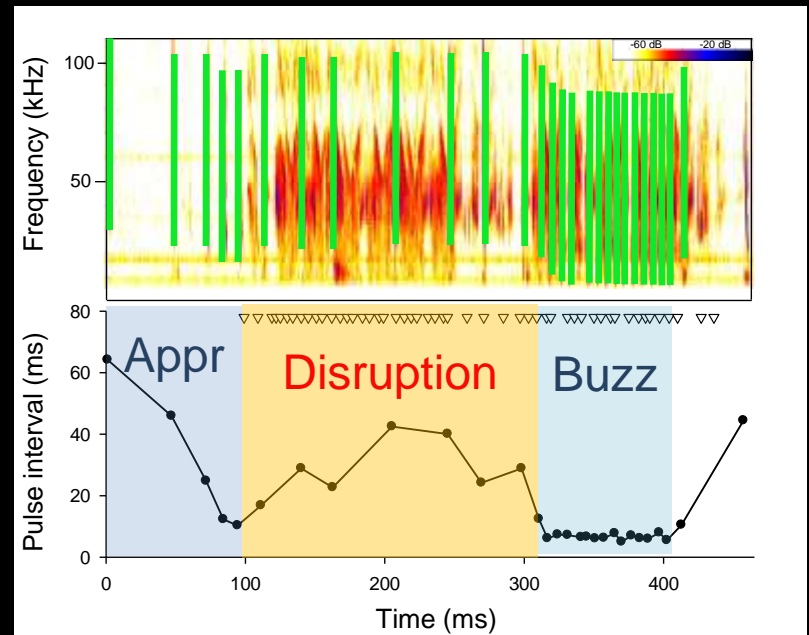
⊙ *B. trigona*

Acoustic Analysis

Attack on control moth



Attack on *Bertholdia trigona*



How do tiger moths jam bat sonar?

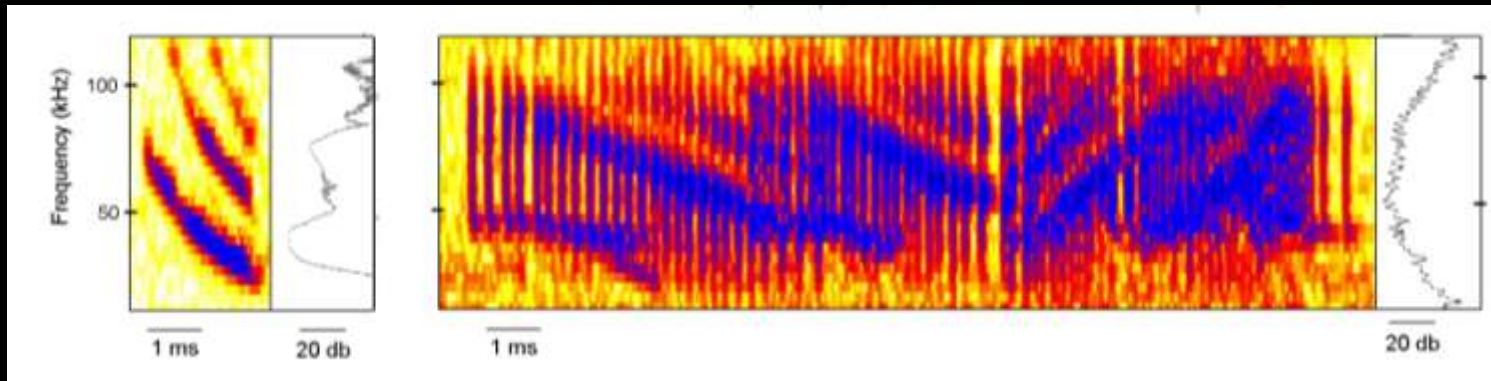


H1: Phantom echoes

- Bats misperceive clicks as echoes from “phantom” objects or targets.



Fullard et al. 1979; Fullard et al. 1994



H2: Masking echoes

- Clicks entirely mask echoes



- **Prediction:** bats fly and echolocate as though moth is not there.

H3: Ranging interference

- Clicks interfere with bat's ability to determine target distance.



← ? →

Prediction: bats miss prey by about 20 cm

Summary

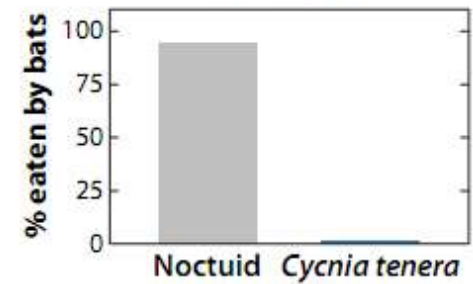
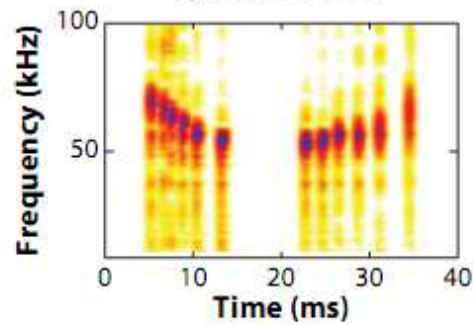
- Most North American tiger moths click to warn bats of their toxicity or to mimic clicks of toxic arctiid relatives
- Some moths (e.g. *Bertholdia trigona*) produce numerous clicks that jam bat sonar
- Moths jam bats by disrupting their neural processing of moth echoes, effectively blurring the acoustic image of the moths

Tymbal organ

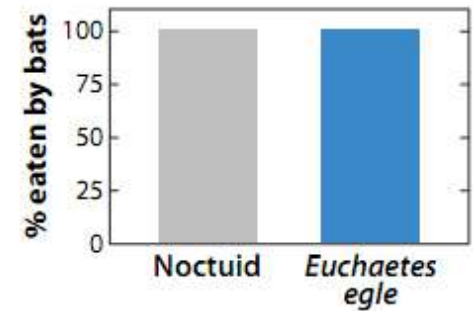
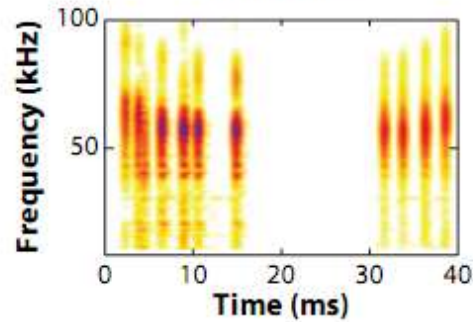
Spectrogram of tymbal sounds

Palatability

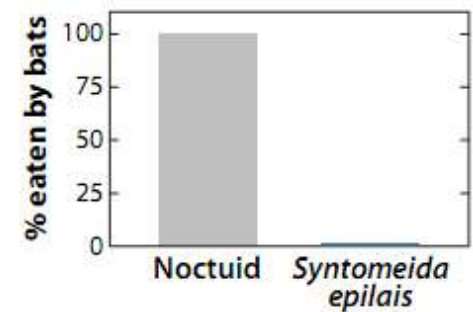
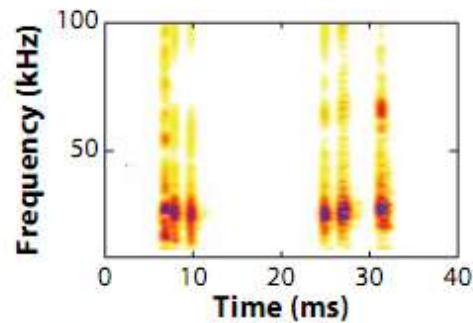
Cycnia tenera
Aposematic



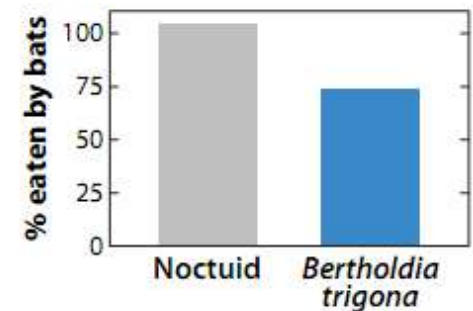
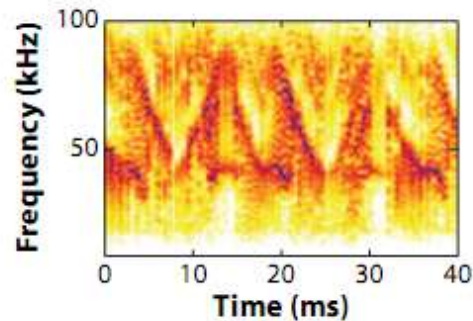
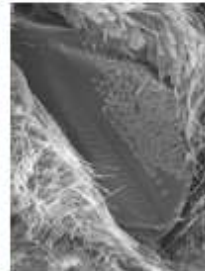
Euchaetes egle
Batesian mimic



Syntomeida epilais
Müllerian mimic



Bertholdia trigona
Sonar jammer



Cygnia tenera

by

Bill Conner

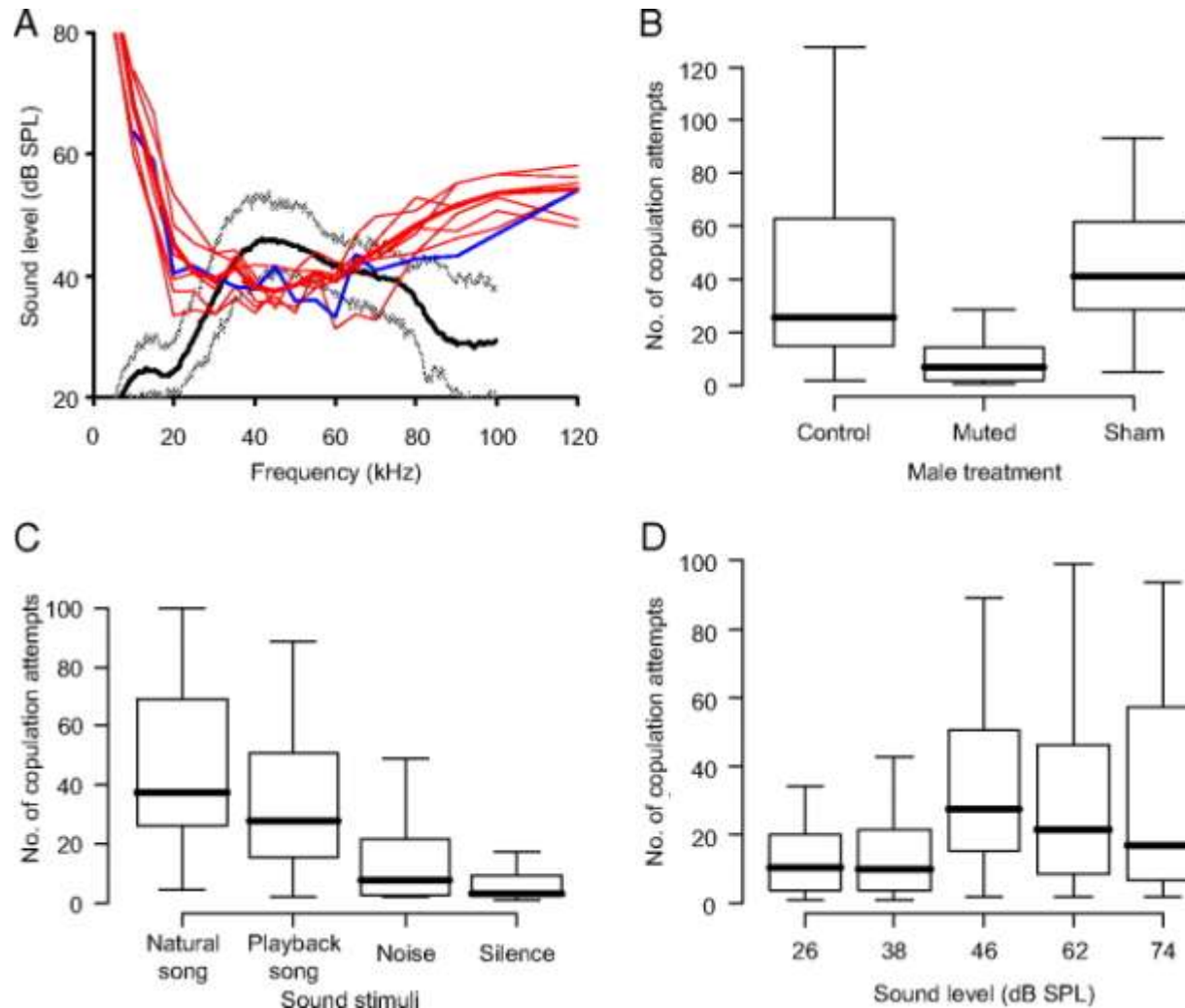
Syntomcida cpilais

by

Mark Sanderford

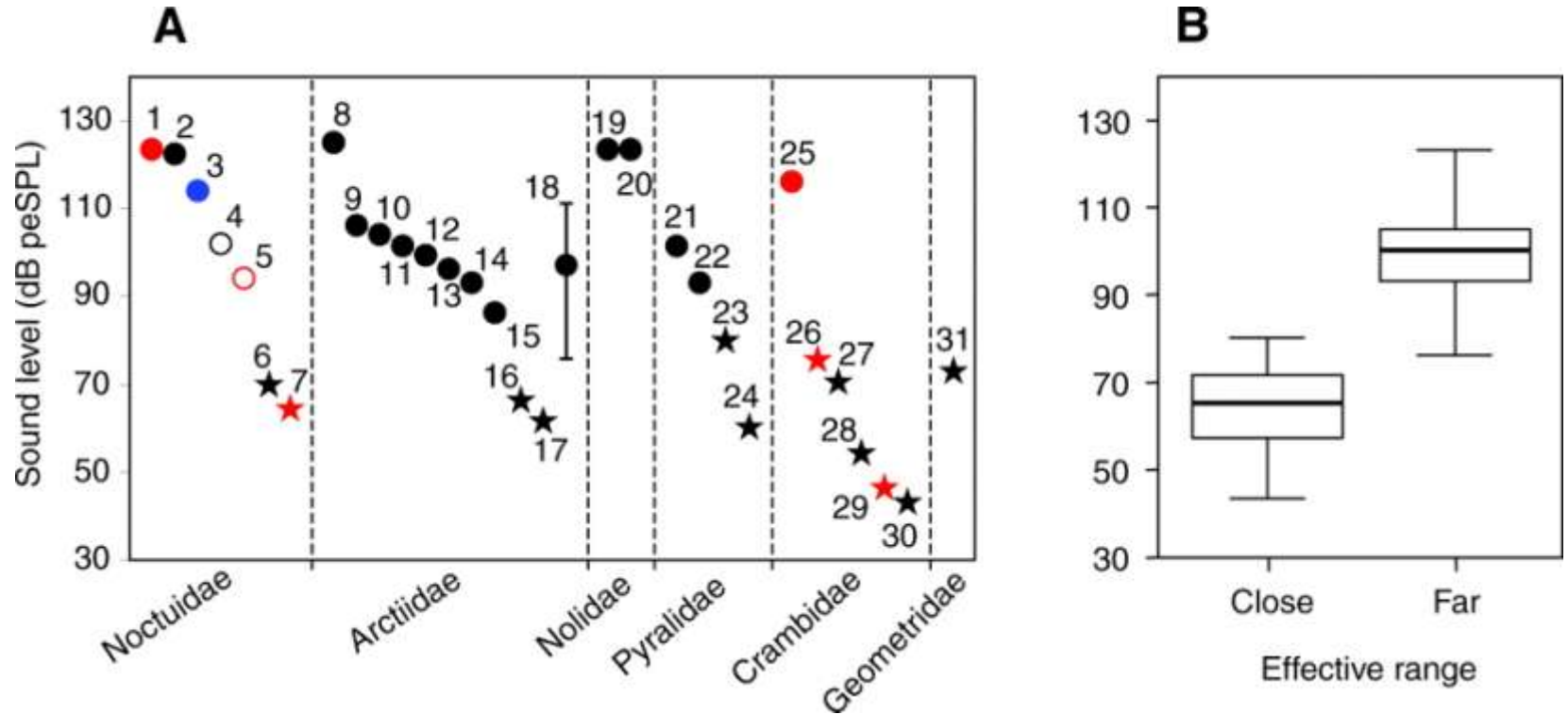


Physiological and behavioral responses of moths.



Nakano R et al. PNAS 2008;105:11812-11817

Pressure levels of sounds emitted by various moths for mating, territorial display or bat-defense.



In a blind survey, 9 of 13 species (70%) from various families were found to use ultrasound in courtship

Nakano R et al. J Exp Biol 2009;212:4072-4078

The Journal of
Experimental
Biology

Male freezing female

- http://www.youtube.com/watch?v=E7kJYU_25To&feature=player_embedded

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- Ryan Wagner
- Zach Walker
- Nick Dowdy
- Jean-Paul Kennedy



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Questions?

